Nanostructured Materials

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A broad study on solid propellant ingredients, space-survivable materials, and hybrid organic-inorganic polymers has been conducted at the Air Force Research Laboratory's (AFRL) Propulsion Directorate at Edwards Air Force Base, California, during the years 1986-2004. This work was carried out primarily with basic research (6.1) funding. Early work on multifunctional isocyanate solid propellant curatives and strained-ring energetic hydrocarbons was quickly replaced by work on hybrid organic-inorganic structural materials; specifically, polyhedral oligomeric silsesquioxane (POSS) compounds. The POSS work represents the vast majority of the effort performed under this study.

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FOREWORD

This final report, entitled "Nanostructured Materials," presents the results of a research study performed under JON 2303M1A3 by AFRL/PRSM, Edwards AFB CA. The Project Manager for the Air Force Research Laboratory was Dr. Steven Svejda.

This report has been reviewed and is approved for release and distribution in accordance with the distribution statement on the cover and on the SF Form 298.

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1.0 EXECUTIVE SUMMARY

1.1 Abstract

A broad study on solid propellant ingredients, space-survivable materials, and hybrid organic-inorganic polymers has been conducted at the Air Force Research Laboratory's (AFRL) Propulsion Directorate at Edwards Air Force Base, California, during the years 1986-2004. This work was carried out primarily with basic research (6.1) funding. Early work on multifunctional isocyanate solid propellant curatives and strained-ring energetic hydrocarbons was quickly replaced by work on hybrid organic-inorganic structural materials; specifically, polyhedral oligomeric silsesquioxane (POSS) compounds. The POSS work represents the vast majority of the effort performed under this study.

The overall goal of the POSS work was to improve the thermal and oxidative resistance of traditional organic polymers, while retaining their low expense, ease of processing, and toughness. The initial efforts on POSS involved the synthesis of POSS monomers, with a concurrent effort to develop understanding the fundamental physical properties of these materials. In the late 1990s, monomer development gave way to incorporation of POSS monomers in polymer systems. Structure/property studies of POSS variants in numerous organic polymers, and related polymer physics work, became the focus of in-house fundamental research after the year 2000. Applied research transitions included POSS-containing solid rocket motor insulation, POSS-lubricants, combustion-resistant POSS polymer blends, and space-survivable polymers. Numerous technology transfers resulted from this work, including POSS-based dental adhesives, improved plastic food packaging, and fire-retardant plastics. Several in-house researchers left the government in 1998 to start Hybrid Plastics Inc., which has commercialized POSS monomers and POSS polymer materials.

1.2 Summary and Recommendations

The Polymer Working Group at Edwards AFB has been a pioneer in developing the area of hybrid organic-inorganic composites, and is a world leader in POSS technology research. A tremendous amount of fundamental scientific information about how to make POSS monomers and polymers, as well as the physical properties of those materials, has been learned under this work effort. The Hybrid Plastics spin-off has been very successful; the company is still expanding operations and income seven years after its formation. Research interest in POSS polymers has exploded. In 1993, there was only one group in the world doing research on this topic (the Edwards group); in 2004, there were over 20 research groups in the US and 15 others worldwide working in this area.

New work to develop fluorine-containing POSS compounds is currently underway, with promising results. POSS-polyimides have shown tremendous potential to become highly survivable replacements for current state-of-the-art polymers used in space applications. It is clear that focused research on POSS nanocomposites will continue well into the future, and full understanding of the ability of nanocomposites to solve a wide range of materials problems will not be realized for a long time to come.

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